OPEN-FILE REPORT 98-11

SEISMIC HAZARD EVALUATION OF THE SEAL BEACH 7.5-MINUTE QUADRANGLE, LOS ANGELES AND ORANGE COUNTIES, CALIFORNIA

1998

DEPARTMENT OF CONSERVATION
Division of Mines and Geology

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PREFACE

With the increasing public concern about the potential for destructive earthquakes in northern and southern California, the State Legislature passed the Seismic Hazards Mapping Act in 1990. The purpose of the Act is to protect the public from the effects of strong ground shaking, liquefaction, landslides or other ground failure, and other hazards caused by earthquakes. The program and actions mandated by the Seismic Hazards Mapping Act closely resemble those of the Alquist-Priolo Earthquake Fault Zoning Act (which addresses only surface fault-rupture hazards) and are outlined below:

1. **The State Geologist** is required to delineate the various "seismic hazard zones."

2. **Cities and Counties**, or other local permitting authorities, must regulate certain development "projects" within the zones. They must withhold the development permits for a site within a zone until the geologic and soil conditions of the project site are investigated and appropriate mitigation measures, if any, are incorporated into development plans.

3. **The State Mining and Geology Board (SMGB)** provides additional regulations, policies, and criteria to guide cities and counties in their implementation of the law. The SMGB also provides criteria for preparation of the Seismic Hazard Zone Maps (Web site http://www.consrv.ca.gov/dmg/shezp/zoneguid/) and for evaluating and mitigating seismic hazards.

4. **Sellers (and their agents)** of real property within a mapped hazard zone must disclose at the time of sale that the property lies within such a zone.

As stated above, the Act directs the State Geologist, through the Division of Mines and Geology (DMG) to delineate seismic hazard zones. Delineation of seismic hazard zones is conducted under criteria established by the Seismic Hazards Mapping Act Advisory Committee and its Working Groups and adopted by the California SMGB.

The Official Seismic Hazard Zone Maps, released by DMG, which depict zones of required investigation for liquefaction and/or earthquake-induced landslides, are available from:

> BPS Reprographic Services
> 149 Second Street
> San Francisco, California 94105
> (415) 512-6550

Seismic Hazard Evaluation Reports, released as Open-File Reports (OFR), summarize the development of the hazard zone map for each area and contain background documentation for use by site investigators and local government reviewers. These Open-File Reports are available for reference at DMG offices in Sacramento, San Francisco, and Los Angeles. Copies of the reports may be purchased at the Sacramento, Los Angeles, and San Francisco offices. In addition, the Sacramento office offers prepaid mail order sales for all DMG OFRs. **NOTE: The Open-File Reports are not available through BPS Reprographic Services.**

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Seismic Hazard Evaluation Reports and additional information on seismic hazard zone mapping in California are available on the Division of Mines and Geology's Internet homepage: http://www.consrv.ca.gov/dmg/shezp/

INTRODUCTION

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation, Division of Mines and Geology (DMG) to delineate seismic hazard zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the seismic hazard zone maps in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within the hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (1997; also available on the Internet at http://www.consrv.ca.gov/dmg/pubs/sp/117/).

The Act also directs SMGB to appoint and consult with the Seismic Hazards Mapping Act Advisory Committee (SHMAAC) in developing criteria for the preparation of the seismic hazard zone maps. SHMAAC consists of geologists, seismologists, civil and structural engineers, representatives of city and county governments, the state insurance commissioner and the insurance industry. In 1991 SMGB adopted initial criteria for delineating seismic hazard zones to promote uniform and effective statewide implementation of the Act. These initial criteria provide detailed standards for mapping regional liquefaction hazards. They also directed DMG to develop a set of probabilistic seismic maps for California and to research methods that might be appropriate for mapping earthquake-induced landslide hazards.

In 1996, working groups established by SHMAAC reviewed the prototype maps and the techniques used to create them. The reviews resulted in recommendations that the 1) process for zoning liquefaction hazards remain unchanged and that 2) earthquake-induced landslide zones be delineated using a modified Newmark analysis.

This Seismic Hazard Evaluation Report summarizes the development of the hazard zone map for each area. The process of zoning for liquefaction uses a combination of Quaternary geologic mapping, historic high-water-table information, and subsurface geotechnical data. The process for zoning earthquake-induced landslides incorporates earthquake loading, existing landslide features, slope gradient, rock strength, and geologic structure. Probabilistic seismic hazard maps, which are the underpinning for delineating seismic hazard zones, have been prepared for peak ground acceleration, mode magnitude, and mode distance with a 10% probability of exceedance in 50 years (Petersen and others, 1996) in accordance with the mapping criteria.

This evaluation report summarizes seismic hazard zone mapping for potentially liquefiable soils and earthquake-induced landslides in the Seal Beach 7.5-minute Quadrangle (scale 1:24,000).

SECTION 1
LIQUEFACTION EVALUATION REPORT

Liquefaction Zones in the Seal Beach 7.5-Minute Quadrangle, Los Angeles and Orange Counties, California

By
Richard B. Greenwood

California Department of Conservation
Division of Mines and Geology

PURPOSE

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation, Division of Mines and Geology (DMG) to delineate Seismic Hazard Zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the seismic zone maps in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within the hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (1997; also available on the Internet at http://www.consrv.ca.gov/dmg/pubs/sp/117/).

This evaluation report summarizes seismic hazard zone mapping for potentially liquefiable soils in the Seal Beach 7.5-minute Quadrangle (scale 1:24,000). This section and Section 2 addressing earthquake-induced landslides, are part of a series that will summarize development of similar hazard zone maps in the state (Smith, 1996). Additional information on seismic hazards zone mapping in California can be accessed on DMG's Internet homepage: http://www.consrv.ca.gov/dmg/shezp/

BACKGROUND

Liquefaction-induced ground failure has historically been a major cause of earthquake damage in southern California. During the 1971 San Fernando and 1994 Northridge earthquakes, significant damage to roads, utility pipelines, buildings, and other structures in the Los Angeles area was caused by liquefaction-induced ground displacement.

Localities most susceptible to liquefaction-induced damage are underlain by loose, water-saturated granular sediments within the upper 40 feet of the ground surface. These geological and ground-water conditions exist in parts of southern California, most notably in some densely populated valley regions and alluviated floodplains. In addition, the opportunity for strong earthquake ground shaking is high because of the many nearby active faults. The combination of these factors constitutes a significant seismic hazard in the southern California region in general, as well as in the Seal Beach Quadrangle.

SCOPE AND LIMITATIONS

Evaluation for potentially liquefiable soils is generally confined to areas covered by Quaternary sedimentary deposits. Such areas consist mainly of alluviated valleys, floodplains, and canyon regions. The evaluation is based on earthquake ground shaking, surface and subsurface lithology, geotechnical soil properties, and ground-water depth data, most of which are gathered from a variety of sources. The quality of the data used varies. Although selection of data used in this evaluation was rigorous, the state of California and the Department of Conservation make no representations or warranties regarding the accuracy of the data obtained from outside sources.

Liquefaction zone maps are intended to prompt more detailed, site-specific geotechnical investigations as required by the Act. As such, liquefaction zone maps identify areas where the potential for liquefaction is relatively high. They do not predict the amount or direction of liquefaction-related ground displacements, or the amount of damage to facilities that may result from liquefaction. Factors that control liquefaction-induced ground failure are the extent, depth and thickness of liquefiable sediments, depth to ground water, rate of drainage, slope gradient, proximity to free-face conditions, and intensity and duration of ground shaking. These factors must be evaluated on a site-specific basis to determine the potential for ground failure at any given project site.

Information developed in the study is presented in two parts: physiographic, geologic, and hydrologic conditions in PART I, and liquefaction potential, opportunity, susceptibility, and zoning evaluations in PART II.

PART I

STUDY AREA LOCATION AND PHYSIOGRAPHY

The onshore portion of the Seal Beach Quadrangle covers an area of about 23 square miles in northwestern Orange County. A very small part of the City of Long Beach within Los Angeles County also lies within the map area at the northwesternmost corner. Parts of the City of Huntington Beach, and several unincorporated communities including Seal Beach, Surfside, and Sunset Beach lie within the quadrangle. The remainder of the quadrangle consists of Orange County land, Bolsa Chica State Beach, U.S. Naval Weapons Station land, and the Anaheim Bay National Wildlife Refuge.

Topographically, much of the Seal Beach Quadrangle consists of flat-lying coastal marsh areas around Anaheim Bay, Huntington Harbour, and Bolsa Chica (Bolsa Bay). These coastal wetlands merge inland with Quaternary sediments of the Los Angeles Basin. To the south, Huntington Mesa forms a distinct elevated terrace above the coastal plain. Elevations range from sea level to about 130 feet on Huntington Mesa in the southern portion of the quadrangle.

The Seal Beach Beach Quadrangle lies within the broad southern margin of the Los Angeles Basin, which culminates abruptly at the Newport-Inglewood Uplift. This uplift is locally characterized by broadly warped coastal mesas composed of late Pleistocene marine terrace deposits. The coastal mesas are deeply incised by antecedent drainages of the latest Pleistocene to earliest Holocene age associated with the regional river systems.

Access to the coastal section of the quadrangle is provided by Pacific Coast Highway (State Highway 1). The San Diego Freeway (405) intersects the northeastern corner of the quadrangle and provides access to the inland sections along Bolsa Avenue, Bolsa Chica Street, Warner Avenue, and Golden West Street.

GEOLOGIC CONDITIONS

Surface Geology

Geologic mapping of late Quaternary alluvial deposits, digitally compiled by the Southern California Areal Mapping Project (1995), was used to evaluate the distribution and character of young, unconsolidated sediments exposed in the Seal Beach Quadrangle. This geologic map relied extensively on early soil surveys (Echmann and others, 1916), to which geologic nomenclature was applied. Additional detail was added from the Long Beach 1:100,000-scale digital geologic map, prepared by the California Division of Mines and Geology (Bezore and others, unpublished). Quaternary geologic contacts received minor modifications in accordance with older 1:62,500-scale U.S. Geological Survey topographic maps (Las Bolsas, 1896) and an older regional soils map (Echmann and others, 1916). Stratigraphic nomenclature was revised to follow the format developed by SCAMP (Morton and Kennedy, 1989). The revised geologic map that was used in this study of liquefaction susceptibility is included as Plate 1.1.

Structurally, most of the Orange County coastal plain is underlain by the broad, northwest-plunging synclinal Los Angeles Basin, which contains up to 4200 feet of relatively unconsolidated Pleistocene marine and nonmarine sediments (Greenwood, 1980b) and up to 170 feet of unconsolidated nonmarine sediments (Fuller, 1980a).

The mapped units fall into four basic age groups: 1) late Pleistocene marine terrace deposits and their veneer of older alluvium (Qvoa/s), dense silty sands that cover Bolsa Chica Mesa, Huntington Beach Mesa, and Landing Hill (in Seal Beach); 2) Holocene alluvial soft silt, silty sand, and sand of distal fan deposits (Qyf/a) associated with the active Santa Ana River alluvial system; 3) modern beach sands (Qm/a), consisting of soft fine- to medium-grained sand; and 4) large areas of artificial fill (af), which cover extensive modern beach sands and lagoonal deposits. An additional description of the geology of the coastal mesas is presented in Section II.

Extensive estuarine deposits occur at the mouth of the abandoned drainage channels of the ancestral Santa Ana River in the Seal Beach Quadrangle. The development of Alamitos Bay and Huntington Harbour altered these surface and near-surface geological materials. The organic tidal muds were extensively dredged and covered in many places with artificial fill (af).

Subsurface Geology and Geotechnical Characteristics

Subsurface properties were described in more than 133 borehole logs in the study area. Subsurface data used for this study include the database compiled by Sprotte and others (1980) for earlier liquefaction studies, and additional data collected for this study. Subsurface data were collected for the current study at the Orange County Public Health Department, Environmental Health Division, Orange County Public Works Department, Construction and Design Divisions, Municipal Water District of Orange County, Caltrans, Southern California District of the California Department of Water Resources, and the California State Architect's Office. Data from previous databases and additional borehole logs were entered into the DMG GIS database. Locations of all exploratory boreholes considered in this investigation are shown on Plate 1.2. Descriptions of characteristics of geologic units recorded on the borehole logs are given below. These descriptions are necessarily generalized, but give the most commonly encountered characteristics of the units (see Table 1.1).

Older alluvium (Qvom/s) covering marine terrace deposits

Older alluvium overlies, but is not differentiated from, late Pleistocene terrace deposits. Ground water is deep throughout these areas, so no extensive effort was made to collect subsurface data. They are generally described as dense to very dense sand and silty sand deposits.

Younger alluvium (Qyf/a)

Younger alluvium associated with the lowlands of the Santa Ana River was not subdivided into "alluvium" and "floodplain" deposits. These deposits consist of soft sand (Qyf/a), silt (Qyf/s), and clay (Qyf/c).

Geologic Map Unit	Material Type	Consistency	Liquefaction Susceptibility
af, artificial fill	sand, silty sand	soft to dense	High
Qm/a, modern beach deposits	Sand	Soft	High
Qyf/a, younger alluvium	silty sand, and sand	soft	High
Qvom/s, marine terrace deposits	silty sand, minor gravel	dense-very dense	Low

Table 1.1. General geotechnical characteristics and liquefaction susceptibility of younger Quaternary units.

Modern beach deposits (Qm)

Modern beach deposits (Qm), which consist of well-sorted, medium- to coarse-grained sand, occur along the shoreline in the Seal Beach Quadrangle.

Artificial fill (af)

Artificial fill in the Seal Beach Quadrangle consists of undifferentiated fills of various ages associated with development of the greater Alamitos Bay and Huntington Harbour complexes and the City of Seal Beach.

Subsurface Stratigraphic Analysis

An analysis of the subsurface geology reveals a dynamic interaction between the development of the Santa Ana River fan and the coastal mesas, whose elevation is related to deformation along the Newport-Inglewood Fault Zone. The reference time-frame of the depositional regime is controlled by the last "low stand" of sea level -- approximately 20,000 years ago (McNeilan and others, 1996). During that time, local drainages became incised because of lower base levels (for example, sea level was 100's of feet below the modern level).

Latest Pleistocene to Earliest Holocene (?) Aquifers

The stratigraphic base of the Holocene deposits is related to the latest Pleistocene rise in sea level that raised stream-base levels, which resulted in the deposition of fan sediments. This latest Pleistocene to earliest Holocene (?) fluvial backfilling of incised drainages controlled the initial distribution of coarse-grained sediments, locally named the Bolsa and Talbert aquifers (Mendenhall, 1905). The depositional process was further discussed and well documented in Poland and others (1956) and Poland (1959). Fuller (1980b) mapped the depth to base, thickness, and lateral distribution of these aquifers and showed the tops to be generally less than 70 feet deep. The immediate scope of the present study focuses on geologic conditions within 50 feet of the ground surface. Nevertheless, an appreciation of these underlying aquifers aids in establishing a temporally constrained (Holocene) stratgraphic framework for determining the nature and distribution of overlying, potentially liquefiable sediments.

Earliest Holocene to modern sediments

The distribution of Holocene sediments, as recorded in early editions of regional soil survey maps (Eckmann and others, 1916), suggests that the Santa Ana River has recently moved back and forth across the Orange County coastal plain from Alamitos Bay to Newport Bay. Historical accounts further support the conclusion that widespread sheet flooding has been the dominant depositional process associated with the Santa Ana River. This went on until the construction of Prado Dam in 1941 (California Department of Water Resources, 1959).

Regional cross sections were constructed using Caltrans and underground tank borehole data, which allowed the definition of at least four and as many as six regional, repetitive, upward-fining sequences of fluvial sediments, with recognizable lateral continuity (Greenwood, 1998). The cross-sectional models became better defined as local cases of crosscutting relationships and longitudinal facies changes also became apparent.

The cross sections demonstrate that the distribution of Holocene flood plain deposits may be as extensive and continuous as the underlying Bolsa and Talbert aquifers. The cross sections also illustrate the distribution of stratigraphically complex interfluvial sediments--as demonstrated by local and regional occurrences of peat deposits.

Stratigraphic units were first identified via correlations of lithology and standard penetration tests (SPT) from deep geotechnical boreholes (generally 60 to 80 feet) drilled along U.S. Interstate highways 5 (I-5) and 405 (I-405). These detailed geotechnical borehole logs were placed in cross sections having a horizontal scale of 1 inch=1000 feet and a vertical scale of 1 inch=10 feet. Same-scale cross sections were similarly prepared along U.S. Interstate highways I-22, I-57, and I-91, within the adjacent Anaheim and the Newport Beach quadrangles. The stratigraphic models were then regionally extrapolated with a series of intersecting north-south and east-west cross sections prepared from environmental geotechnical boreholes (primarily investigations of leaking underground storage tanks), and anchored either by other deep hospital-site boreholes or by detailed water-well logs.

GROUND-WATER CONDITIONS

Saturated conditions reduce the normal effective stress acting on loose, near-surface sandy deposits, thereby increasing the likelihood of liquefaction (Youd, 1973). A ground-water evaluation of alluviated areas was performed in order to determine historically shallowest ground-water levels in the Seal Beach Quadrangle. Ground-water depth data were obtained from compiled geotechnical boreholes, environmental monitoring wells, and water-well logs. The data were plotted onto computer-generated maps of the project area. Areas characterized by historically highest ground water or perched water with depths of less than 40 feet are considered for the purposes of liquefaction hazard zoning. The evaluation was based on first-encountered water levels encountered in geotechnical boreholes and selected water wells. The depths to first-encountered water, free of piezometric influences, were plotted and contoured onto a map showing depths to historically shallowest ground water (Plate 1.2). This map was digitized and used for the liquefaction analysis.

PART II

EVALUATING LIQUEFACTION POTENTIAL

Liquefaction occurs in water-saturated sediments during moderate to great earthquakes. Liquefied sediments are characterized by a loss of strength and may fail, causing damage to buildings, bridges, and other such structures. A number of methods for mapping liquefaction hazard have been proposed; Youd (1991) highlights the principal developments and notes some of the widely used criteria. Youd and Perkins (1978) demonstrate the use of geologic criteria as a qualitative characterization of susceptibility units, and introduce the mapping technique of combining a liquefaction susceptibility map and a liquefaction opportunity map to evaluate liquefaction potential. Liquefaction susceptibility is a function of the capacity of sediments to resist liquefaction and liquefaction opportunity is a function of the seismic ground shaking intensity. The application of the Seed Simplified Procedure (Seed and Idriss, 1971) for evaluating liquefaction potential allows a quantitative characterization of susceptibility of geologic units. Tinsley and others (1985) applied a combination of the techniques used by Seed and others (1983) and Youd and Perkins (1978) for mapping liquefaction hazards in the Los Angeles region. The method applied in this study for evaluating liquefaction potential is similar to that of Tinsley and others (1985), combining geotechnical data analyses, and geologic and hydrologic mapping, but follows criteria adopted by the California State Mining and Geology Board (in press).

LIQUEFACTION OPPORTUNITY

According to the criteria adopted by the California State Mining and Geology Board (in press), liquefaction opportunity is a measure, expressed in probabilistic terms, of the potential for ground shaking strong enough to generate liquefaction. Analyses of in-situ liquefaction resistance require assessment of liquefaction opportunity. The minimum level of seismic excitation to be used for such purposes is the level of peak ground acceleration (PGA) with a 10% probability of exceedance over a 50-year period. The earthquake magnitude is the magnitude that contributes most to the acceleration.

For the Seal Beach Quadrangle, peak accelerations of 0.41 g to 0.56 g resulting from an earthquake of magnitude 6.8 were used for liquefaction analyses. The PGA and magnitude values were derived from maps prepared by Petersen and others (1996) and Cramer and Petersen (1996), respectively. See the ground motion portion (Section 3) of this report for further details.

LIQUEFACTION SUSCEPTIBILITY

Liquefaction susceptibility reflects the relative resistance of soils to loss of strength when subjected to ground shaking. Primarily, physical properties and conditions of soil such as sediment grain-size distribution, compaction, cementation, saturation, and depth govern the degree of resistance. Soils that lack resistance (susceptible soils) are typically saturated, loose sandy sediments. Soils resistant to liquefaction include all soil types that are dry or sufficiently dense. Cohesive soils are generally not considered susceptible to liquefaction.

DMG's map inventory of areas containing soils susceptible to liquefaction begins with evaluation of geologic maps, cross-sections, geotechnical test data, geomorphology, and ground-water hydrology. Soil-property and soil-condition factors such as type, age, texture, color, and consistency, along with historic depths to ground water are used to identify, characterize, and correlate susceptible soils. Because Quaternary geologic mapping is based on similar soil observations, findings can be related to the map units. A qualitative susceptible soil inventory is outlined below and summarized in Table 1.1.

Older alluvium (Qvom/s) covering marine terrace deposits

Older alluvium overlies, but is not differentiated from, late Pleistocene terrace deposits. Ground water is deep throughout the areas of older alluvium, so no extensive effort was made to collect subsurface data. Older alluvium is generally described as dense to very dense sand and silty sand. Liquefaction susceptibility of the unit is low.

Younger alluvium (Qyf/a)

Younger alluvium associated with the lowlands of the Santa Ana River was not subdivided into "alluvium" and "floodplain" deposits. The deposits consist of soft sand (Qyf/a), silt (Qyf/s), and clay (Qyf/c). Where the unit is saturated, liquefaction susceptibility is high.

Modern beach sand deposits (Qm)

Modern beach deposits (Qm), which consist of well-sorted, medium- to coarse-grained sand, occur along the shoreline in the Seal Beach Quadrangle. Where this unit is saturated, liquefaction susceptibility is high.

Artificial fill (af)

Artificial fills commonly overlie young alluvial or estuarine deposits. Because the artificial fills are usually too thin to affect the liquefaction hazard, and the underlying estuarine and alluvial deposits have a high liquefaction susceptibility, they are assumed to have a high susceptibility to liquefaction.

Quantitative Liquefaction Analysis

DMG performs quantitative analysis of geotechnical data to evaluate liquefaction potential using the Seed Simplified Procedure (Seed and Idriss, 1971; Seed and others, 1983; Seed and Harder, 1990; Youd and Idriss, 1997). This procedure calculates soil resistance to liquefaction, expressed in terms of cyclic resistance ratio (CRR) based on standard penetration test (SPT) results, ground-water level, soil density, moisture content, soil type, and sample depth. CRR values are then compared to calculated earthquake-generated shear stresses expressed in terms of cyclic stress ratio (CSR). The factor of safety (FS) relative to liquefaction is: FS=CRR/CSR. FS, therefore, is a quantitative measure of liquefaction potential. Generally, a factor of safety of 1.0 or less, where CSR equals or exceeds CRR, indicates the presence of potentially liquefiable soil. DMG uses FS, as well as other considerations such as slope, free face conditions, and thickness and depth of potentially liquefiable soil, to construct liquefaction potential maps, which then directly translate to Zones of Required Investigation.

Borehole logs compiled for this study include 51 that had blow counts from standard penetration tests or from tests that could be converted to SPTs. Few included all of the required information (SPTs, density, water content, percentage of silt and clay size grains) for a complete Seed Simplified analysis. For those boreholes where SPTs were recorded, the liquefaction analysis was conducted either using data from that borehole or if the other data were lacking, extrapolated from nearby boreholes in similar materials.

LIQUEFACTION ZONES

Criteria for Zoning

The areas underlain by late Quaternary geologic units were included in liquefaction zones using the criteria developed by the Seismic Hazards Mapping Act Advisory Committee and adopted by the California State Mining and Geology Board (in press). Under those criteria, liquefaction zones are areas meeting one or more of the following:

1. Areas known to have experienced liquefaction during historic earthquakes.

2. All areas of uncompacted fills containing liquefaction susceptible material that are saturated, nearly saturated, or may be expected to become saturated.

3. Areas where sufficient existing geotechnical data and analyses indicate that the soils are potentially liquefiable.

4. Areas where existing geotechnical data are insufficient.

In areas of limited or no geotechnical data, susceptibility zones may be identified by geologic criteria as follows:

a) Areas containing soil deposits of late Holocene age (current river channels and their historic floodplains, marshes and estuaries), where the M7.5-weighted peak acceleration that has a

10% probability of being exceeded in 50 years is greater than or equal to 0.10 g and the water table is less than 40 feet below the ground surface; or

b) Areas containing soil deposits of Holocene age (less than 11,000 years), where the M7.5-weighted peak acceleration that has a 10% probability of being exceeded in 50 years is greater than or equal to 0.20 g and the historic high water table is less than or equal to 30 feet below the ground surface; or

c) Areas containing soil deposits of latest Pleistocene age (between 11,000 years and 15,000 years), where the M7.5-weighted peak acceleration that has a 10% probability of being exceeded in 50 years is greater than or equal to 0.30 g and the historic high water table is less than or equal to 20 feet below the ground surface.

Application of SMGB criteria for liquefaction zoning in the Seal Beach Quadrangle is summarized below.

Areas of Past Liquefaction

In the Seal Beach Quadrangle, numerous effects attributed to liquefaction were noted in the Bolsa Chica area and coastal areas of the City of Long Beach following the 1933 Long Beach earthquake. Observed damage and effects include buckled and displaced pavement, fill settlement, surficial cracks, and "mud volcanoes" formed near the north end of Seal Beach (Barrows, 1974; see Plate 1.2).

Areas with Existing Geotechnical Data

The marine terrace deposits and/or older alluvial deposits (Qova/s) in the Seal Beach Quadrangle generally have a dense consistency, high fines content, or deep ground water and, accordingly, have not been included in liquefaction hazard zones. Younger alluvial deposits (Qyf/a) commonly have layers of loose silty sand or sand. Where these deposits are saturated, they are included in a liquefaction hazard zone.

Modern Beach Deposits

Modern beach deposits, which consist of loose, saturated, well sorted, medium- to coarse-grained sand, form the shoreline of Seal Beach Quadrangle. They are included in liquefaction hazard zones.

Artificial Fills

In the Seal Beach Quadrangle artificial fill occurs around Alamitos Bay, Huntington Harbour, and the City of Seal Beach. Residential-related engineered fills are generally too thin to have an impact on liquefaction. Fills that overlie estuarine deposits are more likely to be susceptible to liquefaction. Extensive low-lying areas of artificial fill have been included in liquefaction hazard zones.

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SECTION 2
EARTHQUAKE-INDUCED LANDSLIDE EVALUATION REPORT

Earthquake-Induced Landslide Zones in the Seal Beach 7.5-Minute Quadrangle, Los Angeles and Orange Counties, California

By

Jack R. McMillan

California Department of Conservation
Division of Mines and Geology

PURPOSE

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation, Division of Mines and Geology (DMG) to delineate Seismic Hazard Zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the seismic hazard zone maps in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within the hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (1997; also available on the Internet at http://www.consrv.ca.gov/dmg/pubs/sp/117/).

This evaluation report summarizes seismic hazard zone mapping for earthquake-induced landslides in the Seal Beach 7.5-minute Quadrangle (scale 1:24,000). This section and Section 1 addressing liquefaction, are part of a series that will summarize development of similar hazard zone maps in the state (Smith, 1996). Additional information on seismic hazard zone mapping in California can be accessed on DMG's Internet homepage: http://www.consrv.ca.gov/dmg/shezp/

BACKGROUND

Landslides triggered by earthquakes have historically been a major cause of earthquake damage. Landslides triggered by the 1971 San Fernando, 1989 Loma Prieta, and 1994 Northridge earthquakes were responsible for destroying or damaging numerous homes and other structures, blocking major transportation corridors, and damaging various types of life-line infrastructure. Typically, areas most susceptible to earthquake-induced landslides are on steep slopes and on or adjacent to existing landslide deposits, especially if the earth materials in these areas are composed of loose colluvial soils, or poorly cemented or highly fractured rocks. These geologic and terrain conditions exist in many parts of southern California, most notably in hilly areas already developed or currently undergoing development. In addition, the opportunity for strong earthquake ground shaking is high because of the many nearby active faults. The combination of these factors constitutes a significant seismic hazard in the southern California region, which includes the Seal Beach Quadrangle.

SCOPE AND LIMITATIONS

The methodology used to make this map is based on earthquake ground-shaking estimates, geologic material-strength characteristics and slope gradient. These data are gathered primarily from a variety of outside sources; thus, the quality of the data is variable. Although the selection of data used in this evaluation was rigorous, the state of California and the Department of Conservation make no representations or warranties regarding the accuracy of the data gathered from outside sources.

Earthquake-induced landslide zone maps are intended to prompt more detailed, site-specific geotechnical investigations as required by the Act. As such, these zone maps identify areas where the potential for earthquake-induced landslides is relatively high. Earthquake-generated ground failures that are not addressed by this map include those associated with ridge-top spreading and shattered ridges. No attempt has been made to map potential run-out areas of triggered landslides. It is possible that such run-out areas may extend beyond the zone boundaries. The potential for ground failure resulting from liquefaction-induced lateral spreading of alluvial materials, considered by some to be a form of landsliding, is not specifically addressed by the earthquake-induced landslide zone or this report. See Section 1, Liquefaction Evaluation Report for the Seal Beach Quadrangle, for more information on the delineation of liquefaction zones.

Information developed in the study is presented in two parts: physiographic, and geologic conditions in PART I, and ground shaking opportunity, landslide hazard potential and zoning evaluations in PART II.

PART I

STUDY AREA LOCATION AND PHYSIOGRAPHY

The onshore portion of the Seal Beach Quadrangle covers an area of about 23 square miles in northwestern Orange County. A very small part of the City of Long Beach within Los Angeles County also lies within the map area at the northwesternmost corner. Parts of the City of Huntington Beach, and several unincorporated communities including Seal Beach, Surfside, and Sunset Beach lie within the quadrangle. The remainder of the quadrangle consists of Orange County land, Bolsa Chica State Beach, U.S. Naval Weapons Station land, and the Anaheim Bay National Wildlife Refuge.

Along the coast are Pleistocene wave-cut marine platforms, which are covered by marine deposits. In most cases a nonmarine colluvial cover veneers the terraces. Alluvium and slope wash deposits occur within the major drainages in some areas.

Topographically, much of the Seal Beach Quadrangle consists of flat-lying coastal marsh areas around Anaheim Bay, Huntington Harbour, and Bolsa Chica (Bolsa Bay). These coastal wetlands merge inland with Quaternary sediments of the Los Angeles Basin. To the south, Huntington Mesa forms a distinct elevated terrace above the coastal plain. Elevations range from sea level to about 130 feet on Huntington Mesa in the southern portion of the quadrangle.

Access to the coastal section of the quadrangle is provided by Pacific Coast Highway (State Highway 1). The San Diego Freeway (405) intersects the northeastern corner of the quadrangle and provides access to the inland sections along Bolsa Avenue, Bolsa Chica Street, Warner Avenue, and Golden West Street.

GEOLOGIC CONDITIONS

Surface and Bedrock Geology

Tinsley and others (1985) published a geologic map of the Long Beach Quadrangle at an approximate scale of 1:295,000. This map was enlarged to a scale of 1:24,000 and supplied to DMG by the U.S. Geological Survey. Poland and Piper (1956) also published geologic maps covering the Seal Beach Quadrangle at a scale of 1:31,680. These maps were scanned into the DMG GIS system and digitized. The digital geologic map was modified to reflect the most recent mapping in the area and to include interpretations of observations made during the aerial photograph landslide inventory and field reconnaissance. In the field, observations were also made of exposures, aspects of weathering, and general surface expression of the geologic units. In addition, the relation of the various geologic units to development and abundance of slope failures was noted.

The Seal Beach Quadrangle is underlain entirely by Quaternary sedimentary deposits. These deposits can be divided into two broad types, the lower to upper Pleistocene consolidated sediments of the hills, mesas, and older plains, and Holocene unconsolidated sediments of the gaps and younger plains.

The oldest deposits exposed in the study area are lower to upper Pleistocene undifferentiated older alluvial deposits (Qoa). The lower Pleistocene deposits consist of the San Pedro Formation, not differentiated on the geologic map, which is comprised of sand, gravel, silt and clay.

The upper Pleistocene deposits consist of three units that are undifferentiated on the geologic map. The oldest deposits are unnamed deposits of silt, sand and gravel that are inferred to crop out locally at the edges of the mesas. The next youngest unit is the Palos Verdes Sand, which consists of marine sand and some pebble gravel that crops out locally at the edges of the mesas. The youngest unit is the terrace cover that consists largely of continental reddish-brown sand.

The balance of the quadrangle, exclusive of artificial fill, is underlain by Holocene unconsolidated alluvial sediments (Qya2) deposited by the modern rivers such as the San Gabriel River and unnamed creek and streams. These deposits underlie the flatland areas of the quadrangle.

Modern artificial fill (af) is mapped extensively throughout the harbor facilities and residential portions of the lowlands. A more detailed description of the artificial fill is presented in the Liquefaction section of this report.

Geologic Material Strength

To evaluate the stability of geologic materials under earthquake conditions, they must first be ranked on the basis of their overall shear strength. Shear strength data for the rock units identified on the geologic map were obtained from geotechnical reports prepared by consultants and on file with the local government permitting departments, (see Appendix A). The locations of rock and soil samples taken for shear testing are shown on Plate 2.1.

Shear strength data gathered from the above sources were compiled for each mapped geologic unit, which were then grouped on the basis of average angle of internal friction (average f) and lithologic character. Geologic formations that have little or no shear test information have been added to existing groups on the basis of lithologic and stratigraphic similarities.

The results of the grouping of geologic materials in the Seal Beach Quadrangle are in Tables 2.1 and 2.2.

Structural Geology

The Newport-Inglewood Fault Zone dominates the geologic structure of the Seal Beach Quadrangle. The northwest-trending Newport-Inglewood Fault Zone is marked at the surface by low eroded scarps along en-echelon faults and by a northwest-trending chain of elongated low hills and mesas that extend from Newport Bay to Beverly Hills, (Yerkes and others, 1965; Barrows, 1974). Several strands of the Newport Inglewood Fault Zone cross the Seal Beach

SEAL BEACH QUADRANGLE SHEAR STRENGTH GROUPINGS							
	Formation Name	**Number Tests**	**Mean Phi Value**	**Group Phi (Mean/Median (deg.)**	**Group C Mean/Median (psf)**	**Phi Values Used in Stability Analyses**	**Similar Lithology: No Data**
GROUP 1	af Qvom/a	5 8	33 34.9	34.4/35	103/100	34	Qvom/c Qvom/s
GROUP 2	Qyf/a	27	30.2	30.2/30	186/135	30	Qyf/c Qyf/s

Table 2.1. Summary of the shear strength statistics for the Seal Beach Quadrangle.

SHEAR STRENGTH GROUPS FOR THE SEAL BEACH QUADRANGLE	
GROUP 1	**GROUP 2**
Af Qvom/a Qvom/s Qvom/c	Qyf/a Qyf/s Qyf/c

Table 2.2. Summary of the shear strength groups for the Seal Beach Quadrangle.

Quadrangle including the Seal Beach Fault on Landing Hill and Bolsa Chica Mesa and the north and south branches of the Inglewood Fault on Huntington Beach Mesa. The orientation of structural elements of the zone is generally attributed to right-lateral, strike-slip faulting at depth.

Landslide Inventory

The evaluation of earthquake-induced landsliding requires an up-to-date and complete picture of the previous occurrence of landsliding. An inventory of the existing landslides in the entire Seal Beach quadrangle was prepared using interpretation of stereo paired aerial photographs of the study area and limited field reconnaissance. However, no landslides that meet the mapping criteria established by DMG were identified in the Seal Beach Quadrangle.

PART II

EARTHQUAKE-INDUCED LANDSLIDE GROUND SHAKING OPPORTUNITY

Design Strong-Motion

The Newmark analysis used in delineating the earthquake-induced landslide zones requires the selection of a design earthquake strong-motion record. For the Seal Beach Quadrangle, the selection was based on an estimation of probabilistic ground motion parameters for modal magnitude, modal distance, and peak ground acceleration (PGA). The parameters were estimated from maps prepared by DMG for a 10% probability of being exceeded in 50 years (Petersen and others, 1996; Cramer and Petersen, 1996). The parameters used in the record selection are:

Modal Magnitude:	6.8 to 7.0
Modal Distance:	2.5 to 5.0 km
PGA:	0.39 to 0.49 g

The strong-motion record selected was the Channel 3 (N35°E horizontal component) University of Southern California Station #14 recording from the magnitude 6.7 Northridge Earthquake (Trifunac and others, 1994). This record had a source to recording site distance of 8.5 km and a PGA of 0.59 g. The selected strong-motion record was not scaled or otherwise modified prior to analysis.

Displacement Calculation

To develop a relationship between the yield acceleration (a_y; defined as the horizontal ground acceleration required to cause the factor of safety to equal 1.0) and Newmark displacements, the design strong-motion record was integrated twice for a given a_y to find the corresponding displacement, and the process repeated for a range of a_y (Jibson, 1993). The resulting curve in Figure 2.1 represents the full spectrum of displacements that can be expected for any combination of geologic material strength and slope angle, as represented by the yield acceleration. We used displacements of 30, 15 and 5 cm as criteria for rating levels of earthquake shaking damage on the basis of the work of Youd (1980), Wilson and Keefer (1983), and the DMG pilot study for earthquake-induced landslides (McCrink and Real, 1996). Applied to the curve in Figure 2.1, these displacements correspond to yield accelerations of 0.076, 0.129 and 0.232 g. Because these yield acceleration values are derived from the design strong-motion record, they represent the significant ground-shaking opportunity thresholds for the Seal Beach Quadrangle.

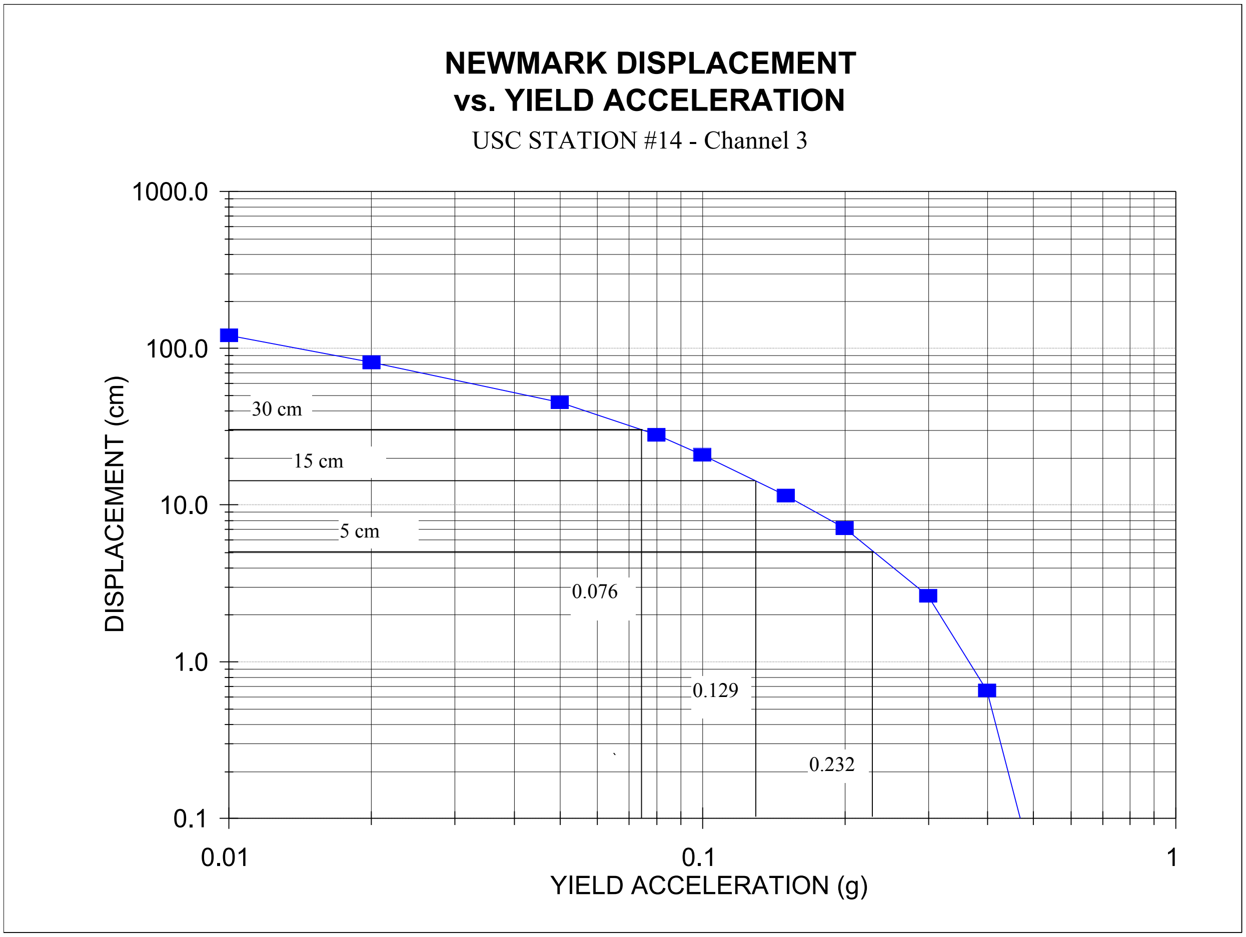

Figure 2.1. Yield acceleration vs. Newmark displacement for the USC Station # 14 strong-motion record from the 17 January 1994 Northridge, California Earthquake.

EARTHQUAKE-INDUCED LANDSLIDE HAZARD POTENTIAL

Terrain Data

The calculation of slope gradient is an essential part of evaluating slope stability under earthquake conditions. To calculate slope gradient for the terrain within the Seal Beach Quadrangle, a Level 2 digital elevation model (DEM) was obtained from the U.S. Geological Survey. This DEM has a 10-m horizontal resolution and a 7.5-m vertical accuracy (USGS, 1993) and was prepared from topographic contours based on 1963 photographs.

Areas that have undergone large-scale grading since 1963 as part of residential development were identified (see Plate 2.1) on 1: 40,000-scale aerial photography flown in 1994 and 1995 (NAPP, 1994). Photogrammetric DEM's covering the graded areas were prepared by the U.S. Bureau of Reclamation with ground control points established by DMG. The photogrammetric DEM's were then merged into the USGS DEM, replacing the areas of out-dated elevation data. Surrounding quadrangle DEM's were merged with the Seal Beach DEM to avoid the loss of data at the quadrangle edges when the slope calculations were performed.

Slope-gradient maps were made from both sets of DEM's using a third-order finite-difference center-weighted algorithm (Horn, 1981). The slope-gradient map was used in conjunction with the geologic strength map to prepare the earthquake-induced landslide hazard potential map.

Stability Analysis

A slope stability analysis was performed for each geologic material strength group at slope increments of 1 degree. An infinite-slope failure model under unsaturated slope conditions was assumed. A factor of safety was calculated first, followed by the calculation of yield acceleration from Newmark's equation:

$$a_y = (FS - 1)g \sin \alpha$$

where FS is the Factor of Safety, g is the acceleration due to gravity, and α is the direction of movement of the slide mass, in degrees measured from the horizontal, when displacement is initiated (Newmark, 1965). For an infinite slope failure α is the same as the slope angle.

The yield acceleration calculated by Newmark's equation represents the susceptibility to earthquake-induced failure of each geologic material strength group for a range of slope gradients. The acceleration values were compared with the ground shaking opportunity, defined by Figure 2.1, to determine the earthquake-induced landslide hazard potential. Based on the criteria described in Figure 2.1 above, if the calculated yield acceleration was less than 0.076 g, expected displacements could be greater than 30 cm, and a HIGH (H on Table 2.3) hazard potential was assigned. Likewise, if the calculated a_y fell between 0.076 and 0.129 g a MODERATE (M on Table 2.3) potential was assigned, between 0.129 and 0.232 a LOW (L on Table 2.3) potential was assigned, and if a_y were greater than 0.232 g a VERY LOW (VL on Table 2.3) potential was assigned. Table 2.3 summarizes the results of the stability analyses. The earthquake-induced landslide hazard potential map was prepared by combining the geologic material-strength map and the slope map according to this table.

EARTHQUAKE-INDUCED LANDSLIDE ZONE

Criteria for Zoning

Earthquake-induced landslide zones were delineated using criteria adopted by the California State Mining and Geology Board (in press). Under those criteria, earthquake-induced landslide zones are areas meeting one or more of the following:

1. Areas known to have experienced earthquake-induced slope failure during historic earthquakes.

SEAL BEACH QUADRANGLE HAZARD POTENTIAL MATRIX							
Geologic Material Strenth Group	**Mean Phi**	**SLOPE CATEGORY (Percent)**					
		I 0-28	**II 29-39**	**III 40-44**	**IV 45-55**	**V 56-61**	**VI >61**
GROUP 1	34	VL	VL	VL	L	M	H
GROUP 2	30	VL	L	M	H	H	H

Table 2.3. Hazard potential matrix for earthquake-induced landslides in the Seal Beach Quadrangle. Shaded area indicates hazard potential levels included in the hazard zone.

2. Areas identified as having past landslide movement, including both landslide deposits and source areas.

3. Areas where CDMG's analyses of geologic and geotechnical data indicate that the geologic materials are susceptible to earthquake-induced slope failure.

Existing Landslides

Studies of the types of landslides caused by earthquakes (Keefer, 1984) show that re-activation of the whole mass of deep-seated landslide deposits is rare. However, it has been observed that the steep scarps and toe areas of existing landslides, which formed as a result of previous landslide movement, are particularly susceptible to earthquake-induced slope failure. In addition, because they have been disrupted during landslide movement, landslide deposits are inferred to be weaker than coherent, undisturbed, adjacent source rocks. Finally, we felt that a long duration, San Andreas fault-type earthquake could be capable of initiating renewed movement in existing deep-seated landslide deposits. Therefore, all existing landslides identified in the inventory with a definite or probable confidence of interpretation were included in the hazard zone.

Geologic and Geotechnical Analysis

On the basis of a DMG pilot study (McCrink and Real, 1996), the earthquake-induced landslide zone includes all areas determined to lie within the High, Moderate, and Low levels of hazard potential. Therefore, as shown in Table 2.3, geologic material strength group 2 is included in the zone for all slopes greater than 28%, and strength group 1, the strongest rock types, were zoned for slope gradients above 44%. This results in less than 0.05% of the land (15 acres) in the Seal Beach Quadrangle lying within the earthquake-induced landslide zone.

ACKNOWLEDGMENTS

The author thanks staff from Leighton and Associates, the City of Seal Beach and the Orange County Department of Public Works and Planning Department for assistance in obtaining geotechnical information used in the preparation of this report. Technical review of the methodology was provided by Bruce Clark, Randy Jibson, Robert Larson, Scott Lindvall, and J. David Rogers, who are members of the State Mining and Geology Board's Seismic Hazards Mapping Act Advisory Committee Landslides Working Group. At DMG, special thanks to Bob Moskovitz, Teri McGuire, Scott Shepherd and Barbara Wanish for their Geographic Information System operations support and Joy Arthur for designing and plotting the graphic displays associated with the earthquake-induced landslide zone map.

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APPENDIX A
SOURCES OF ROCK STRENGTH DATA

SOURCE	NUMBER OF TESTS SELECTED
City of Seal Beach	2
Division of Mines and Geology, Environmental Impact Reports File	25
Leighton and Associates	13
Total number of tests used to characterize the units in the Seal Beach Quadrangle	40

SECTION 3
GROUND SHAKING EVALUATION REPORT

Potential Ground Shaking in the Seal Beach 7.5-Minute Quadrangle, Los Angeles and Orange Counties, California

By

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Division of Mines and Geology

PURPOSE

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation, Division of Mines and Geology (DMG) to delineate Seismic Hazard Zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the Seismic Hazard Zone Maps in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within the hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (1997; also available on the Internet at http://www.consrv.ca.gov/dmg/pubs/sp/117/).

This section of the evaluation report summarizes the ground motions used to evaluate liquefaction and earthquake-induced landslide potential for zoning purposes. Included, are ground motion and related maps, a brief overview on how these maps were prepared, precautionary notes concerning their use, and related references. The maps provided herein are presented at a scale of approximately 1:150,000 (scale bar provided on maps), and show the full 7.5- minute quadrangle and portions of the adjacent eight quadrangles. They can be used to assist in the specification of earthquake loading conditions ***for the analysis of ground failure*** according to the “Simple Prescribed Parameter Value” method (SPPV) described in the site investigation guidelines (California State Mining and Geology Board, 1997). Alternatively, they can be used as a basis for comparing levels of ground motion determined by other methods with the statewide standard.

This section and Sections I and II, addressing liquefaction and earthquake-induced landslide hazards, constitute a report series that summarizes development of seismic hazard zone maps in the state. Additional information on seismic hazard zone mapping in California can be accessed on DMG’s Internet homepage: http://www.consrv.ca.gov/dmg/shezp/

EARTHQUAKE HAZARD MODEL

The estimated ground shaking is derived from the seismogenic sources as published in the statewide probabilistic seismic hazard evaluation released cooperatively by the California Department of Conservation, Division of Mines and Geology, and the U.S. Geological Survey (Petersen and others, 1996). That report documents an extensive 3-year effort to obtain consensus within the scientific community regarding fault parameters that characterize the seismic hazard in California. Fault sources included in the model were evaluated for long-term slip rate, maximum earthquake magnitude, and rupture geometry. These fault parameters, along with historical seismicity, were used to estimate return times of moderate to large earthquakes that contribute to the hazard.

The ground shaking levels are estimated for each of the sources included in the seismic source model using attenuation relations that relate earthquake shaking with magnitude, distance from the earthquake, and type of fault rupture (strike-slip, reverse, normal, or subduction). The published hazard evaluation of Petersen and others (1996) only considers uniform firm-rock site conditions. In this report, however, we extend the hazard analysis to include the hazard of exceeding peak horizontal ground acceleration (PGA) at 10% probability of exceedance in 50 years on spatially uniform conditions of rock, soft rock, and alluvium. These soil and rock conditions approximately correspond to site categories defined in Chapter 16 of the Uniform Building Code (ICBO, 1997), which are commonly found in California. We use the attenuation relations of Boore and others (1997), Campbell (1997), Sadigh and others (1997), and Youngs and others (1997) to calculate the ground motions.

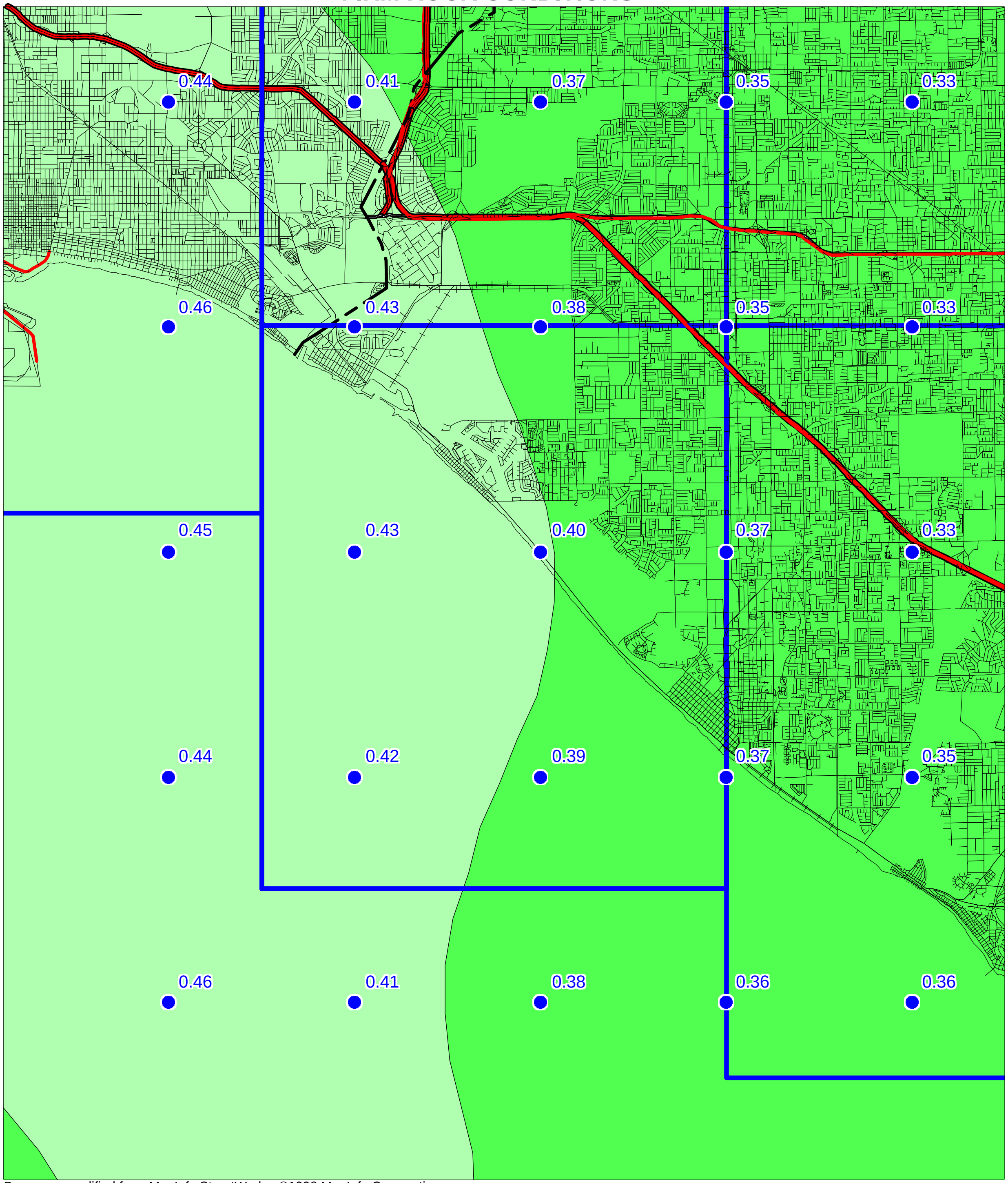
The seismic hazard maps for ground shaking are produced by calculating the hazard at sites separated by about 5 km. Figures 3.1 through 3.3 show the hazard for PGA at 10% probability of exceedance in 50 years assuming the entire map area is firm rock, soft rock, or alluvial site conditions respectively. The sites where the hazard is calculated are represented as dots and ground motion contours as shaded regions. The quadrangle of interest is outlined by bold lines and centered on the map. Portions of the eight adjacent quadrangles are also shown so that the trends in the ground motion may be more apparent. We recommend estimating ground motion values by selecting the map that matches the actual site conditions, and interpolating from the calculated values of PGA rather than the contours, since the points are more accurate.

SEAL BEACH 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)

1998

FIRM ROCK CONDITIONS



Base map modified from MapInfo StreetWorks ©1998 MapInfo Corporation

0 2.5 5

Kilometers

Department of Conservation
Division of Mines and Geology

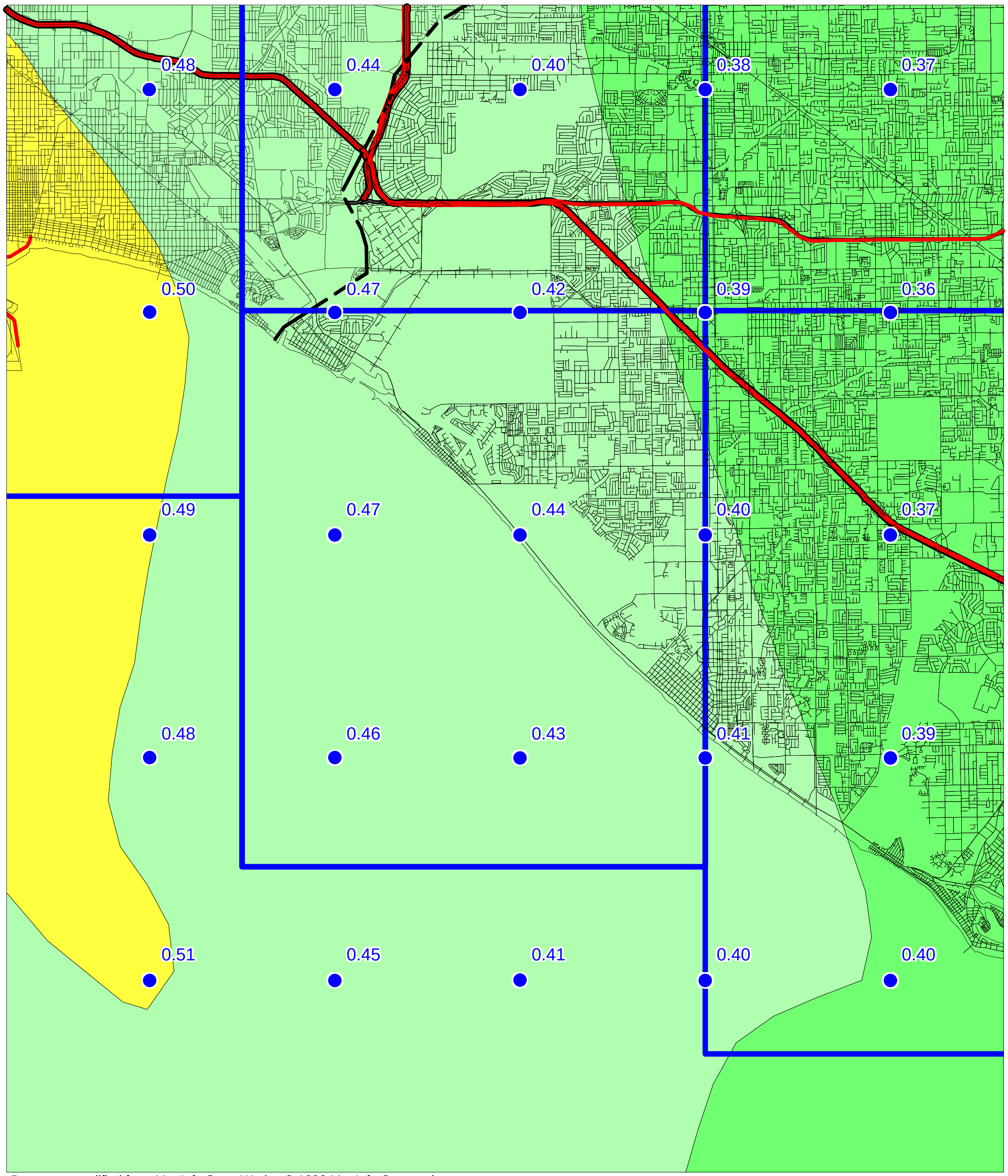
Figure 3.1

SEAL BEACH 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)

1998

SOFT ROCK CONDITIONS



Base map modified from MapInfo StreetWorks © 1998 MapInfo Corporation

0 2.5 5
Kilometers

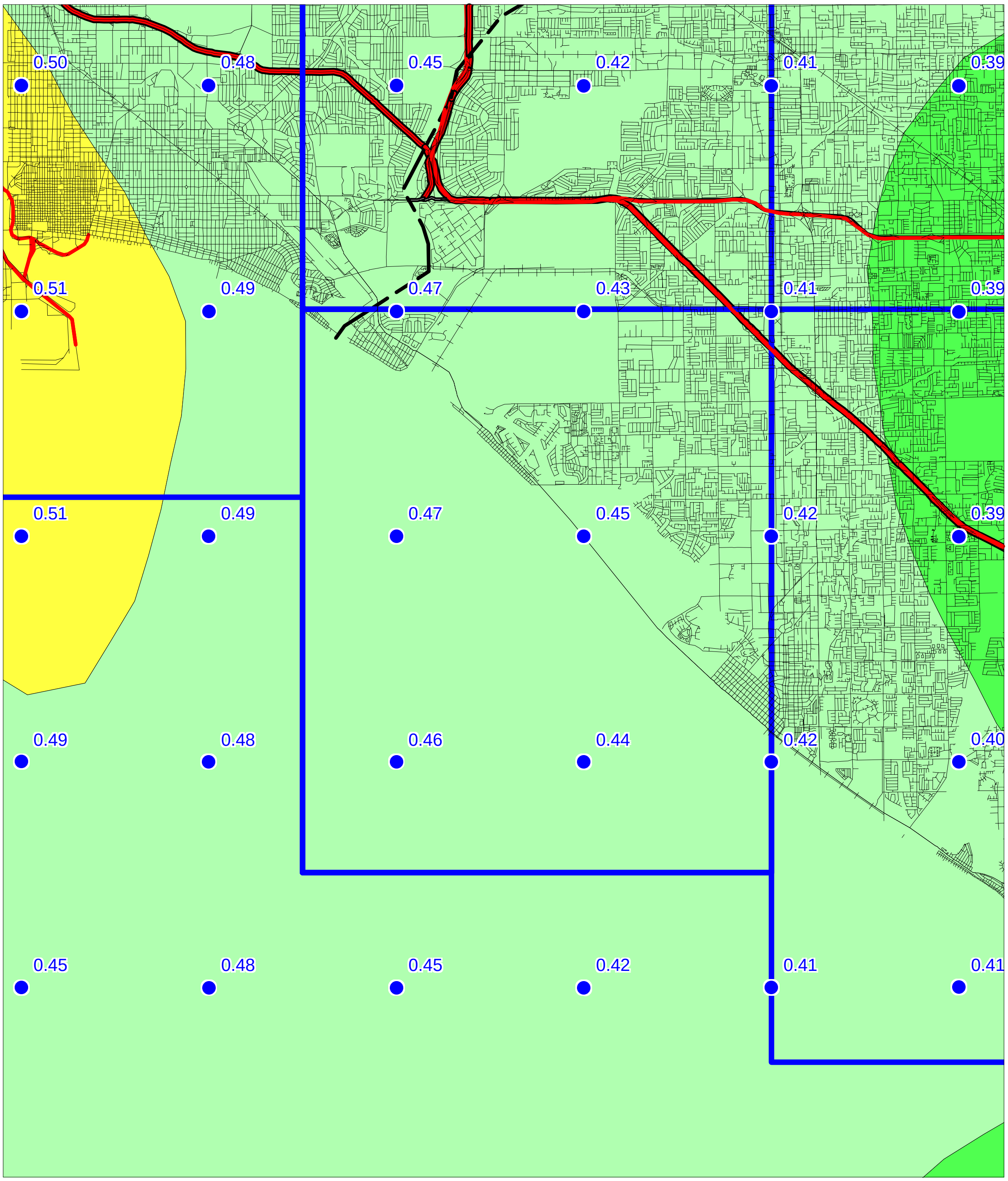
Department of Conservation
Division of Mines and Geology

Figure 3.2

SEAL BEACH 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)
1998

ALLUVIUM CONDITIONS



Base map modified from MapInfo Street Works ©1998 MapInfo Corporation

0 2.5 5
Kilometers

Department of Conservation
Division of Mines and Geology

Figure 3.3

APPLICATIONS FOR LIQUEFACTION AND LANDSLIDE HAZARD ASSESSMENTS

Deaggregation of the seismic hazard identifies the contribution of each of the earthquakes (various magnitudes and distances) in the model to the ground motion hazard for a particular exposure period (see Cramer and Petersen, 1996). The map in Figure 3.4 identifies the magnitude and the distance (value in parentheses) of the earthquake that contributes most to the hazard at 10% probability of exceedance in 50 years on alluvial site conditions (*predominant earthquake*). This information gives a rationale for selecting a seismic record or ground motion level in evaluating ground failure. However, it is important to keep in mind that more than one earthquake may contribute significantly to the hazard at a site, and those events can have markedly different magnitudes and distances. For liquefaction hazard the predominant earthquake magnitude from Figure 3.4 and PGA from Figure 3.3 (alluvium conditions) can be used with the Youd and Idriss (1997) approach to estimate cyclic stress ratio demand. For landslide hazard the predominant earthquake magnitude and distance can be used to select a seismic record that is consistent with the hazard for calculating the Newmark displacement (Wilson and Keefer, 1983). When selecting the predominant earthquake magnitude and distance, it is advisable to consider the range of values in the vicinity of the site and perform the ground failure analysis accordingly. This would yield a range in ground failure hazard from which recommendations appropriate to the specific project can be made. Grid values for predominant earthquake magnitude and distance should **not** be interpolated at the site location, because these parameters are not continuous functions.

USE AND LIMITATIONS

The statewide map of seismic hazard has been developed using regional information and is ***not appropriate for site specific structural design applications***. Use of the ground motion maps prepared at larger scale is limited to estimating earthquake loading conditions for preliminary assessment of ground failure at a specific location. We recommend consideration of site-specific analyses before deciding on the sole use of these maps for several reasons.

1. The seismogenic sources used to generate the peak ground accelerations were digitized from the 1:750,000-scale fault activity map of Jennings (1994). Uncertainties in fault location are estimated to be about 1 to 2 kilometers (Petersen and others, 1996). Therefore, differences in the location of calculated hazard values may also differ by a similar amount. At a specific location, however, the log-linear attenuation of ground motion with distance renders hazard estimates less sensitive to uncertainties in source location.

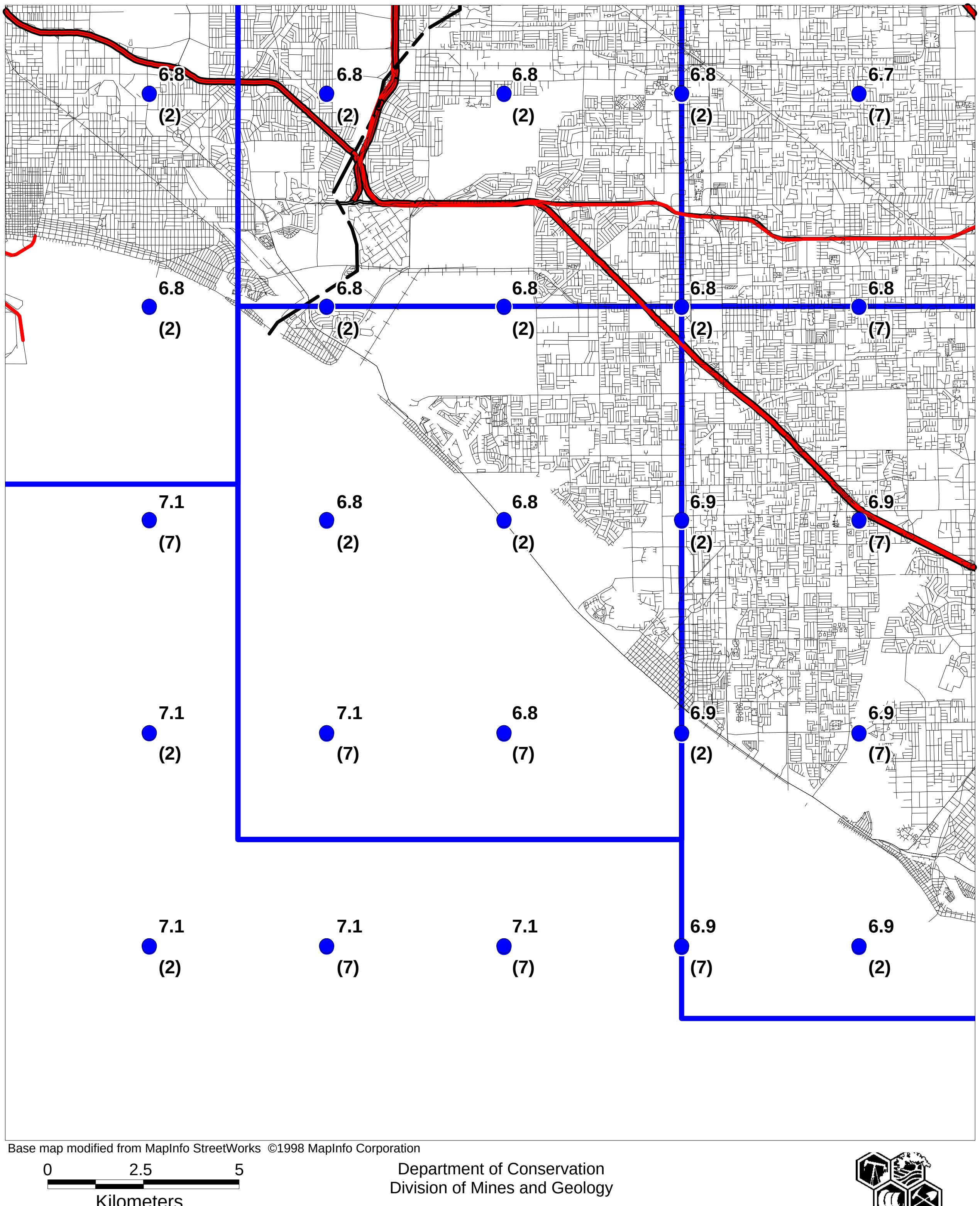
2. The hazard was calculated on a grid at sites separated by about 5 km (0.05 degrees). Therefore, the calculated hazard may be located a couple kilometers away from the site. We have provided shaded contours on the maps to indicate regional trends of the hazard model. However, the contours only show regional trends that may not be apparent from points on a single map. Differences of up to 2 km have been observed between contours and individual

SEAL BEACH 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION

1998

PREDOMINANT EARTHQUAKE
Magnitude (Mw)
(Distance (km))



Department of Conservation
Division of Mines and Geology

Figure 3.4

ground acceleration values. *We recommend that the user interpolate PGA between the grid point values rather than simply using the shaded contours*.

3. Uncertainties in the hazard values have been estimated to be about +/- 50% of the ground motion value at two standard deviations (Cramer and others, 1996).

4. Not all active faults in California are included in this model. For example, faults that do not have documented slip rates are not included in the source model. Scientific research may identify active faults that have not previously been recognized. Therefore, future versions of the hazard model may include other faults and omit faults that are currently considered.

5. A map of the predominant earthquake magnitude and distance is provided from the deaggregation of the probabilistic seismic hazard model. However, it is important to recognize that a site may have more than one earthquake that contributes significantly to the hazard. Therefore, in some cases earthquakes other than the predominant earthquake should also be considered.

Because of its simplicity, it is likely that the SPPV method (California State Mining and Geology Board, 1997) will be widely used to estimate earthquake shaking loading conditions for the evaluation of ground failure hazards. It should be kept in mind that ground motions at a given distance from an earthquake will vary depending on site-specific characteristics such as geology, soil properties, and topography, which may not have been adequately accounted for in the regional hazard analysis. Although this variance is represented to some degree by the recorded ground motions that form the basis of the hazard model used to produce Figures 3.1, 3.2, and 3.3, extreme deviations can occur. More sophisticated methods that take into account other factors that may be present at the site (site amplification, basin effects, near source effects, etc.) should be employed as warranted. The decision to use the SPPV method with ground motions derived from Figures 3.1, 3.2, or 3.3 should be based on careful consideration of the above limitations, the geotechnical and seismological aspects of the project setting, and the “importance” or sensitivity of the proposed building with regard to occupant safety.

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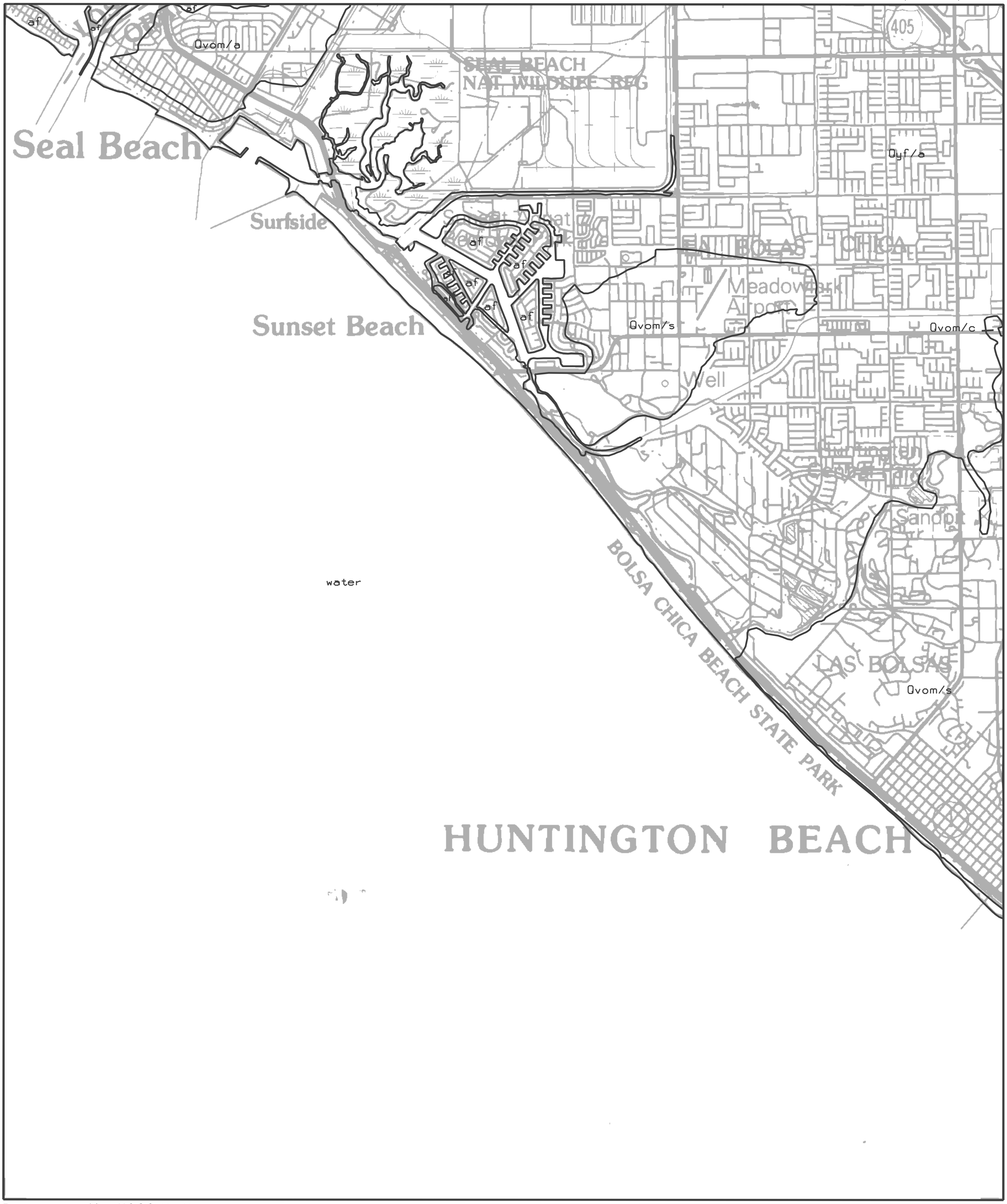
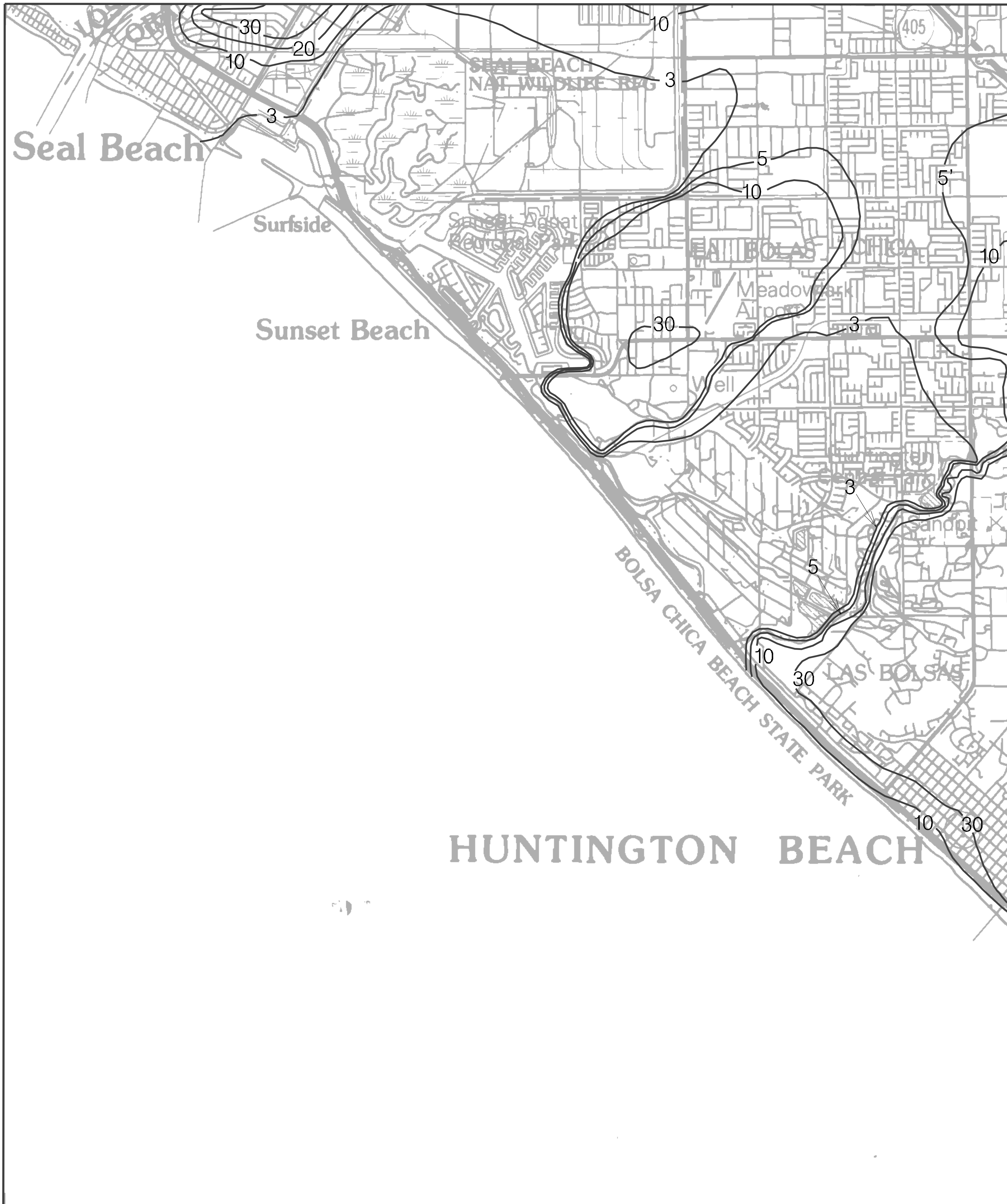


Base map enlarged from U.S.G.S. 30 x 60–minute series

Plate 1.1 Quaternary Geologic Map of the Seal Beach Quadrangle.
See Geologic Conditions section in report for descriptions of the units.

ONE MILE
SCALE



Base map enlarged from U.S.G.S. 30 x 60–minute series

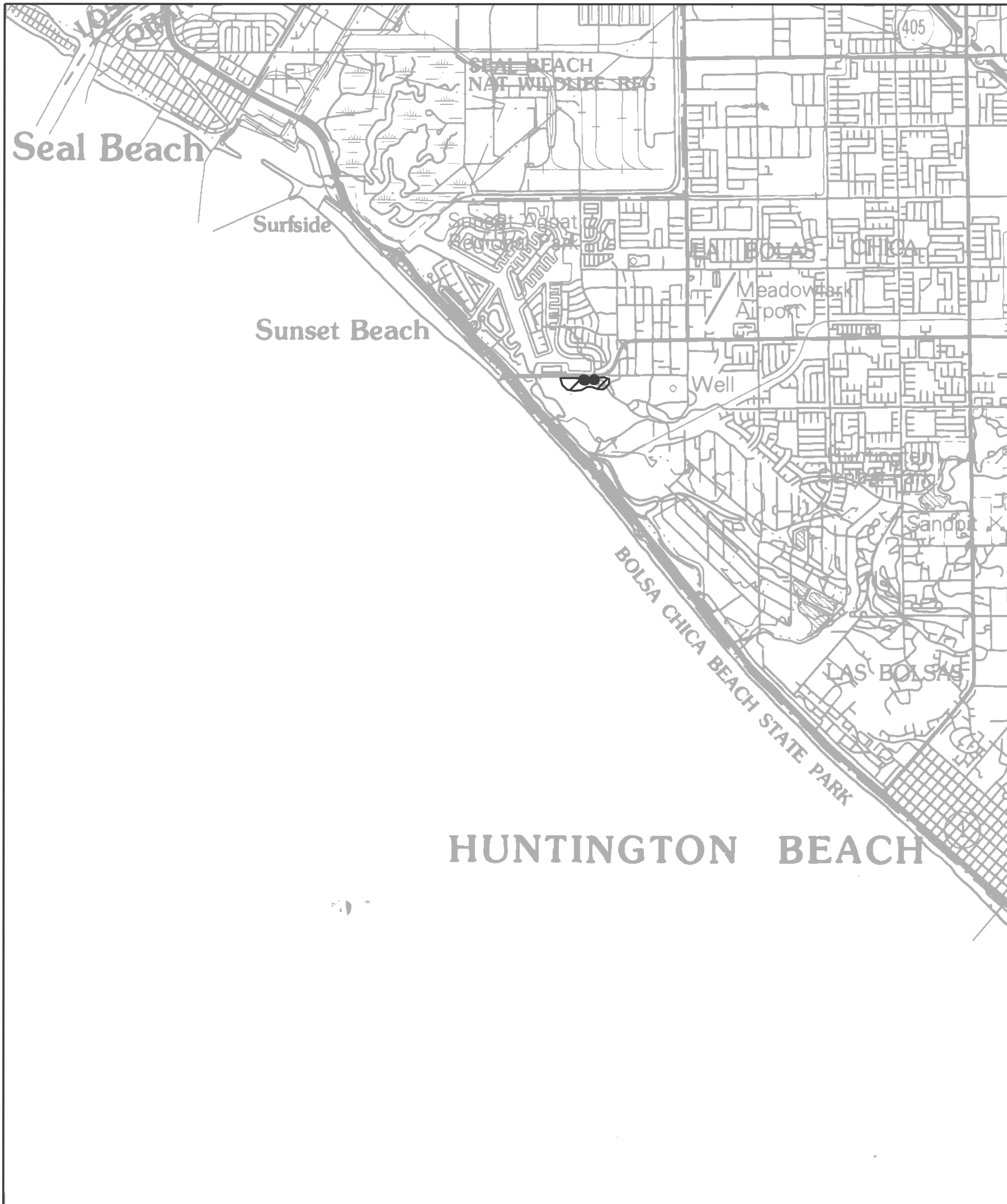
Plate 1.2 Historically Highest Ground Water Contours and Borehole Log Data Locations, Seal Beach Quadrangle.

● Borehole Site

30 Depth to ground water in feet

ONE MILE

SCALE



Base map enlarged from U.S.G.S. 30 x 60–minute series

Plate 2.1 Data collection site and tract location map, Seal Beach Quadrangle.

● shear test sample location

tract report with multiple borings

ONE MILE

SCALE